REMARKS

Attached hereto is a fee for two (2) independent claims in excess of three independent claims.

Claims 1, 3, 5, and 7-17 are currently pending in this application. This Amendment currently amends claims 3 and 5. Claims 2, 4, and 6 are canceled without prejudice or disclaimer. New claims 9-17 are added. No new matter is added to currently amended claims 3 and 5, or to new claims 9-17. Claims 3 and 5 are currently amended to merely clarify the subject matter of the claims and in no way narrow the scope of the claims in order to overcome the prior art or for any other statutory purpose of patentability.

Notwithstanding any claim amendments of the present Amendment or those amendments that may be made later during prosecution, Applicant's intent is to encompass equivalents of all claim elements. Reconsideration in view of the foregoing amendments and the following remarks is respectfully requested.

Claim 6 stands rejected under 35 U.S.C. §112, second paragraph.

Claims 1 and 7 stand rejected under 35 U.S.C. §103(a) as unpatentable over U.S. Patent No. 5,523,589 to Edmond et al. (hereinafter, Edmond) in view of U.S. Patent No. 6,072,189 to Duggan. Claims 3, 5, 6, and 8 stand rejected under 35 U.S.C. §103(a) as unpatentable over Edmond in view of Duggan and further in view of U.S. Patent No. 6,258,617 to Nitta et al. (hereinafter, Nitta).

These rejections are respectfully traversed in view of the following discussion.

I. THE CLAIMED INVENTION

The claimed invention, as described in claim 1, is directed to a group III nitride compound semiconductor device of a successively laminated structure that comprises a substrate, a buffer layer formed directly on the substrate, <u>an intervening layer formed directly on the buffer layer</u>, the intervening layer comprising $In_XGa_{1-X}N$, where $0<X<1$, and <u>a light-emitting layer formed directly on the intervening layer</u>, the light-emitting layer comprising $In_YGa_{1-Y}N$, where $0<Y<1$, in which <u>a first In composition ratio of the intervening layer, X, changes from a first interface with the buffer layer to a second interface with the light-emitting layer, such that, the first In composition ratio, X, at the second interface becomes</u>

substantially equal to a second In composition ratio, Y, of the light-emitting layer.

The claimed invention, as described in claim 3, is directed to a group III nitride compound semiconductor device of a successively laminated structure that comprises a substrate, a buffer layer formed directly on said substrate and having a buffer layer lattice constant, an intervening layer formed directly on said buffer layer, said intervening layer comprising $Al_aGa_bIn_{1-a-b}N$, where $0<a<1$, $0<b<1$, and $a+b<1$, and a light-emitting layer formed directly on said intervening layer, said light-emitting layer comprising $In_YGa_{1-Y}N$, where $0<Y<1$, and having a light-emitting layer lattice constant, in which composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, a first lattice constant of said intervening layer at said first interface is substantially equal to said buffer layer lattice constant and changes to a second lattice constant at said second interface, which is substantially equal to said light-emitting layer lattice constant.

An aspect of the present invention allows the composition ratios of the intervening layer at the second interface to be substantially equal to those of composition ratios of the light-emitting layer. Thus, at the second interface, lattice constants of both the intervening layer and the light-emitting layer are substantially equal to minimize lattice stresses and improve crystallinity of the light-emitting layer. The improved crystallinity of the light-emitting layer results in a greater intensity of emitted light.

Another aspect of the present invention allows the composition ratios of the intervening layer at the first interface to provide a lattice constant that is substantially equal to a lattice constant of the buffer layer. Thus, at the first interface, lattice stresses are minimized, resulting in improved crystallinities of the buffer layer and intervening layer.

Another aspect of the present invention allows control of band gaps by changing the composition ratios of Al and In within the intervening layer and the light-emitting layer.

Another aspect of the present invention allows homoepitaxial growth of both the intervening layer upon the buffer layer and the light-emitting layer upon the intervening layer at substantially equal temperatures.

II. THE PRIOR ART REJECTIONS

A. The Edmond Reference

Fig. 1 of Edmond illustrates an LED 20 that comprises a buffer layer 23 on a substrate 21 (col. 5, lines 18-19) and a double heterostructure comprising an active layer 25 along with upper 26 and lower 27 heterostructure layers adjacent to the active layer (col. 5, lines 30 and 41-44). The heterostructure layers 26 and 27 are preferably formed of a composition selected from the group consisting of gallium nitride, aluminum nitride, indium nitride, and ternary Group III nitrides having the formula $A_XB_{1-X}N$, where A and B are Group III elements and where X is zero, one, or a fraction between zero and one (col. 5, lines 44-49).

Edmond also discloses that in the heterostructure 24 illustrated in Fig. 1, the active layer 25 can preferably comprise indium gallium nitride and the upper and lower heterostructure layers 26 and 27 will preferably comprise aluminum gallium nitride (col. 6, lines 3-6).

Fig. 3 of Edmond illustrates a third embodiment, in which the buffer layer comprises first and second layers 47 and 48, respectively (col.6, lines 61- 62 and col.7, lines 1-3). The first layer 47 is formed of a graded composition of silicon carbide aluminum gallium nitride $(SiC)_XAl_YGa_{1-Y}N$ in which the portion adjacent the substrate 43 is substantially entirely silicon carbide and the portion furthest from the substrate is substantially entirely aluminum gallium nitride, with the portions therebetween being progressively graded in content from predominantly silicon carbide to predominantly aluminum gallium nitride (col. 7, lines 3-11).

The second layer 48 is formed of another graded component of aluminum gallium nitride (col. 7, lines 12-13). In preferred embodiments, the composition of the graded second layer 48 is graded from a composition matching the composition of the first buffer layer 47 at the point where the layers 47 and 48 meet, to a composition matching the composition of the lowest layer of the double heterostructure 45 (col. 7, lines 14-19).

Claim 1 recites at least the features of "an intervening layer formed directly on said buffer layer, said intervening layer comprising $In_XGa_{1-X}N$, where $0<X<1$; and a light-emitting layer formed directly on said intervening layer, ... wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said second interface becomes substantially equal to a second In composition ratio, Y, of said light-

emitting layer."

Edmond discloses a light emitting diode comprising a buffer layer 23, a lower heterostructure layer 27, presumably corresponding to the claimed invention's intervening layer, and an active layer 25, presumably corresponding to the claimed invention's light-emitting layer.

<u>Nowhere does Edmond teach or suggest a graded lower heterostructure layer</u> that is analogous to "an intervening layer ... comprising $In_XGa_{1-X}N$, ... wherein <u>a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer,</u>" as recited in claim 1. Thus, Edmond cannot provide the claimed invention's benefits of homoepitaxial growth of both the lower heterostructure layer and the active layer.

In addition, Edmond discloses that in the heterostructure 24 illustrated in Fig. 1, the active layer 25 can preferably comprise indium gallium nitride and the upper and lower heterostructure layers 26 and 27 will preferably comprise aluminum gallium nitride. <u>Edmond clearly teaches away from a heterostructure 24, in which both the active layer 25 and the lower heterostructure layer comprise indium gallium nitride</u>. In fact, this preferred structure of Edmond corresponds to the related art of the Specification and is subject to the same problems, namely heteroepitaxial growth of the active layer upon a lower heterostructural layer and requiring different growth temperatures for the active layer and the lower heterostructural layer.

In contrast, <u>both the intervening layer and the light-emitting layer of the claimed invention comprise indium gallium nitride</u>. Thus, homoepitaxial growth of the light-emitting layer may occur upon the intervening layer at the same temperature at which the intervening layer was grown. It is such homoepitaxial growth of the light-emitting layer in the present invention that improves crystallinity of the light-emitting layer and consequently, improved intensity of light emission.

B. The Duggan Reference

Fig. 1 of Duggan illustrates a light-emitting diode structure of a GaN buffer layer 2 grown on a sapphire substrate 1, followed by an n-doped GaN contact layer 3, an n-doped (AlGa)N cladding layer 4, and a Zn-doped (InGa)N active layer 5 (col. 2, line 65 to col. 3,

line 8)

Fig. 7 of Duggan is a schematic diagram of a light-emitting diode structure having the same constituent layers as the structure of Fig. 1, but with the introduction of graded layers 41, 42, 43 and 44 at the interfaces between the (AlGa)N cladding layers 4 and 6 and both the GaN contact layers 3 and 7 and the (InGa)N active layer 5 (col. 7, lines 55-61). While graded layers 41, 42, 43 and 44 are shown at each of these four interfaces in the diagram of Fig. 7, it understood that the invention may provide graded layers 42 and 43 only at the interfaces between the (AlGa)N cladding layers 4 and 6 and the (InGa)N active layer 5, no such graded layers being provided in this case at the interfaces between the cladding layers 4 and 6 and the contact layers 3 and 7 (col. 7, line 61 to col. 8, line 1).

Claim 1 recites at least the features of "an intervening layer formed directly on said buffer layer, said intervening layer comprising $In_XGa_{1-X}N$, where 0<X<1; and a light-emitting layer formed directly on said intervening layer, ... wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said second interface becomes substantially equal to a second In composition ratio, Y, of said light-emitting layer."

The graded layer of Duggan is disposed between the (InGa)N active layer and the (AlGa)N cladding layer, which in turn is disposed on an n-doped GaN contact layer, which further in turn is disposed on a GaN buffer layer.

In contrast, the intervening layer of the claimed invention, which comprises a gradation of the In composition ratio, is disposed between and directly contacts the light-emitting layer and the buffer layer. Hence, the structure of the LED of the claimed invention comprises two less layers than that of Duggan, which results in reduced complexity of fabrication and lower cost.

In addition, the Examiner cites Duggan to support the modification of Edmond by introducing graded layers. However, the Applicant respectfully submits that nowhere does Edmond suggest the desirability of such a combination, as required by *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990). See, MPEP §2143.01.

In fact, Edmond is obviously aware of the use of graded layers in the fabrication of LEDs, since Edmond discloses a third embodiment, in which the first layer of a buffer layer is

formed of a graded composition of silicon carbide aluminum gallium nitride $(SiC)_X Al_Y Ga_{1-Y} N$, where the portion adjacent the substrate is substantially entirely silicon carbide and the portion furthest from the substrate is substantially entirely aluminum gallium nitride, and in which a second layer of the buffer layer is formed of another graded component of aluminum gallium nitride. Thus, there would be no need to rely on the combination of Edmond and Duggan absent impermissible hindsight reconstruction.

Yet, nowhere does Edmond teach or suggest the use of a graded layer, which is directly in contact with the buffer layer and the light-emitting layer, i.e., the intervening layer of the claimed invention.

Applicant respectively submits that nowhere does Edmond suggest the desirability of the Office Action's proposed modification of using a graded layer between the buffer layer and the light-emitting layer of the claimed invention, as required by *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990). Therefore, Applicant further respectfully submits that the combination of Duggan with Edmond does not properly constitute a *prima facie* case of obviousness under 35 U.S.C. §103(a). Withdrawal of the rejection of claim 1 and claim 7, which depends from claim 1, under 35 U.S.C. §103(a) as unpatentable over Edmond in view of Duggan is respectfully solicited.

C. The Nitta Reference

Nitta discloses a gallium-nitride-based compound semiconductor blue light emitting diode 1 that has a sapphire substrate 100 (col. 2, lines 65-66 and Fig. 1). On the substrate 100, a gallium-nitride-based semiconductor buffer layer 101 and a gallium-nitride-based n-type semiconductor contact layer 102 are formed (col. 2, line 66 to col. 3, line 3). On layer 102, a gallium-nitride-based n-type semiconductor clad layer 103, and a gallium-nitride-based semiconductor active layer 104 are formed (col. 3, lines 3-5).

The invention of Nitta employs an InAlGaN compound semiconductor as the gallium-nitride-based semiconductor (col. 3, lines 11-12).

The gallium-nitride-based n-type semiconductor clad layer 103 forms the n side of a p-i-n junction that forms a light emitting region, where values for the parameters of In(x)Al(y)Ga(1-x-y) of the gallium-nitride-based n-type semiconductor clad layer 103 are properly adjusted according to a required wavelength of light (col. 3, lines 31-35).

The gallium-nitride-based semiconductor active layer 104 is substantially an intrinsic semiconductor layer that forms a main part of the light emitting region (col. 3, lines 40-43). Values for the parameters of In(x)Al(y)Ga(1-x-y) of the gallium-nitride-based semiconductor active layer 104 are properly adjusted according to a required wavelength of light (col. 3, lines 43-47).

Claim 3 recites at least the features of "an intervening layer formed directly on said buffer layer, said intervening layer comprising $Al_aGa_bIn_{1-a-b}N$, ... wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer."

Nitta discloses a blue light emitting element comprising a gallium-nitride-based n-type semiconductor clad layer 103, presumably corresponding to the claimed invention's intervening layer, and a gallium-nitride-based semiconductor active layer 104, presumably corresponding to the claimed invention's light-emitting layer.

Nowhere does Nitta teach or suggest that the gallium-nitride-based n-type semiconductor clad layer is analogous to "an intervening layer ... comprising $Al_aGa_bIn_{1-a-b}N$, ... wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer," as recited in claim 3. The composition ratios of Nitta's gallium-nitride-based semiconductor layers are fixed. Thus, Nitta cannot provide the claimed invention's benefits of homoepitaxial growth of both the gallium-nitride-based n-type semiconductor clad layer and the gallium-nitride-based semiconductor active layer.

Also, the gallium-nitride-based n-type semiconductor clad layer of Nitta, which presumably corresponds to the claimed invention's intervening layer, is disposed between the gallium-nitride-based semiconductor active layer and the gallium-nitride-based n-type semiconductor contact layer, which is in turn disposed on the gallium-nitride-based semiconductor buffer layer.

In contrast, the intervening layer of the claimed invention, which comprises a gradation of the In composition ratio, is disposed directly on the buffer layer and directly contacts the light-emitting layer. Hence, the structure of the LED of the claimed invention comprises one less layer than that of Nitta, which results in reduced complexity of fabrication and lower cost.

As argued above, Edmond also does not teach or suggest a lower heterostructure layer in which a composition ratio of a component changes from a first interface with a buffer layer to a second interface with a light-emitting layer, as does the claimed invention.

As also argued above, the graded layer of Duggan is disposed between the (InGa)N active layer and the (AlGa)N cladding layer, which in turn is disposed on an n-doped GaN contact layer, which further in turn is disposed on a GaN buffer layer. Hence, the structure of the LED of the claimed invention comprises two less layers than that of Duggan.

In addition, as respectfully argued above, the proposed combination of Duggan with Edmond does not properly constitute a *prima facie* case of obviousness under 35 U.S.C. §103(a) because nowhere does Edmond suggest the desirability of such a combination, as required by *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990). Likewise, nowhere does Nitta suggest the desirability of such a combination. Therefore, Applicant further respectfully submits that the combination of Duggan with Edmond and/or Nitta does not properly constitute a *prima facie* case of obviousness under 35 U.S.C. §103(a).

Withdrawal of the rejection of claim 3 and claims 5, 6, and 8, which depend from claim 3, under 35 U.S.C. §103(a) as unpatentable over Edmond in view of Duggan and further in view of Nitta is respectfully solicited.

III. THE 35 U.S.C. §112,SECOND PARAGRAPH, REJECTION

The Office Action rejects claim 6 under 35 U.S.C. §112, second paragraph. By this Amendment, claim 6 is canceled without prejudice or disclaimer; hence, the rejection of claim 6 is moot.

IV. CONCLUSION

In view of the foregoing, Applicant submits that claims 1, 3, 5, and 7-17 all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

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